BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D. C. 20024

B69 06068

SUBJECT: Some Preliminary Results of Tradeoffs Between Walking and the Use of Mobility Aids During Lunar Surface EVA - Case 320

DATE: June 19, 1969

FROM: P. Benjamin

MEMORANDUM FOR FILE

INTRODUCTION

The utility of mobility aids on the lunar surface depends upon the manner in which they are used. This analysis employs a computer program to determine those regions in which mobility aids provide greater operational efficiency than that obtained by walking. The application of these results should enhance the effectiveness with which mobility aids are employed. Some preliminary results are reported here.

Two extreme cases must be considered at the outset. Should the weight carrying requirement exceed an astronaut's capability, clearly a mobility aid of some sort is required for the purpose of moving this payload. On the other extreme, if the terrain cannot be negotiated by a mobility device, but is acceptable for walking, only the latter mode can be used. In this analysis, the region between these extremes is treated implicitly. That is, increasing roughness of the terrain and/or increasing weight carrying requirements are reflected in decreased riding and/or walking speed.

In contrast to previous work in this area, in this analysis, metabolic rate, rather than time, is used as the cost factor. That is, the EVA has no arbitrary time limitation, but is terminated when the cumulative metabolic load exceeds a fixed value. Thus, return to the LM occurs at a time defined by a redline which results from a determination of the metabolic load requirements for return.

The computer program permits a parametric study by means of an EVA simulation. Parameters which are varied are sample site separation, time spent at each side, walking speed, and riding speed. For each combination of parameters the computer program simulates an EVA and calculates the number of sample sites visited, the cumulative time spent at the sample sites, the total duration of the EVA, and the time spent at the last site visited. In addition, a check on the simulation is performed by determining the total metabolic expenditure.

(NASA-CR-106566) SOME PRELIMINARY RESULTS OF TRADEOFFS BETWEEN WALKING AND THE USE OF MOBILITY AIDS DURING LUNAR SURFACE EVA (Bellcomm, Inc.) 10 p N79-73068

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ABSTRACT

A parametric study of the use of mobility aids and walking during lunar surface EVA attempted to determine those regions in which each mode of locomotion has greater effectiveness. In contrast to most work performed previously in this area, metabolic rate, rather than time, was used as the cost factor. The parameters which were varied were sample site separation, time spent at each site, walking speed, and riding speed. The payoff was assumed to be the cumulative time spent at the sampling sites during the EVA.

The results showed that for the assumptions used and for relatively small site separations (less than 1 km) very high riding speeds are required to match the return obtained with fairly low walking speeds. The primary advantage of the use of a mobility device over walking occurs when large loads are to be carried over relatively smooth terrain, or where a very large distance separates the LM from sites which will be visited for only a very short time. The analysis is continuing with variations of the assumptions used.

Sample output from the program is shown in Tables 1 and 2. The computer program is available from the author.

ASSUMPTIONS

A maximum metabolic expenditure of 4800 BTU is used in this analysis, representing current PLSS capability. It is expected that changes in this value due to the development of improved life support systems or redefinition of operational constraints may modify the specific results obtained in this analysis, but will probably not significantly modify the form of the tradeoff. The BTU return redline is determined by subtracting from this total load the metabolic cost of return to the LM, transferring samples into the LM, and ingress.

It is assumed for this analysis that return to the LM will occur from a point which is within 1 km of the LM and in the nominal transportation mode and rate for the EVA.* If a mobility device with an average speed of 7 km/hr is used for the EVA, the return redline is calculated based upon a 1 km ride at 7 km/hr. Similarly, if the EVA is conducted walking at an average speed of 2 km/hr, the return redline is based on the metabolic cost of walking 1 km at 2 km/hr.

The average metabolic rates assumed for specific activities within the EVA timeline and the times required (where applicable) for these activities are shown in Table 3. The use of the average rate implies a summation over all detailed variations in metabolic load during an activity. For example, if the EVA involves walking at 3 km/hr at a metabolic cost of 1250 BTU/hr for 20 minutes followed by a 10 minute rest period with a 500 BTU/hr expenditure, the average metabolic rate is 1000 BTU/hr and the average walking speed is 2 km/hr. The EVA timeline used is shown in Figure 1.

As implied, the values of site separation, time at site, walking speed, and riding speed are also averaged. A single constant average walking or riding speed is used for each simulated EVA. Similarly, for each EVA the site separation is constant throughout and the time spent at each site is the same (except, perhaps, for the last site).

RESULTS

In this study, average walking rate was varied between 1 km/hr and 5 km/hr and riding rate between 1 km/hr and 15 km/hr

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*This does not imply any restriction on radius of operation or site location except, perhaps, for the last site visited, which may have to be within 1 km of the LM.

in 1 km/hr increments. The average site separation stepped through 0.25 km increments between 0.25 km and 2.0 km, while the time at each site varied between 15 minutes and 1 hour in 15 minute increments. The results of the analysis for the extreme cases of 15 minutes at each site and 1 hour at each site are shown in Figures 2 and 3.

The payoff in this study is assumed to be the cumulative time spent at the sampling sites during the EVA. The curves drawn on Figures 2 and 3 are lines of equal payoff. In Figure 2, for example, for a walking rate of 3 km/hr and a site separation of 0.75 km a mobility device must average 5 km/hr or greater to provide the same return in terms of cumulative time at the sites. If the site separation is 0.25 km the payoff obtained by using a mobility device moving at 15 km/hr can be matched by walking at 2 km/hr. Thus, for all points to the right and below each curve a greater return is obtained by walking and to the left and above each curve a greater return is obtained by riding. The dashed line connects points of equal speed in both modes.

The curves show that for small site separations, for all average times at the sites, the metabolic cost of ingressing and egressing the mobility device frequently far outweighs any advantage it gains by its increased speed or metabolic load savings obtained while riding. This occurs because the metabolic cost of moving between the sites is approximately the same as the cost of ingress and egress. Thus, if the cost of walking at 2 km/hr between two sites is 130 BTU, it is smaller than the combined cost of riding at 6 km/hr between these sites (40 BTU), plus the ingress and egress (120 BTU) required. For low average site times (Figure 2) increasing site separation reduces the advantage of walking over riding, until at large separations (2 km) the same yield is obtained in walking at some speed as in riding at that same speed.

For high average site times (Figure 3) only a few sites are visited and a large portion of the available metabolic load is expended at the site with a much smaller part attributable to moving between sites. The cost of servicing, ingressing, and egressing the mobility device is still greater than the slow, but steady, progress obtained by walking. The curves of Figure 3 shift more in favor of walking (over Figure 2) due to the combined effect of predominance of site related activity and the basic cost of mobility device servicing as a function of the few sites visited.

CONCLUSIONS

For relatively small site separations very high riding speeds are required to match the return obtained with fairly low walking speeds. As site separation increases, the advantage of walking over riding decreases. As time at the site increases, so does the advantage of walking over riding. Of course, these results are predicated upon the assumptions used and the range of parameters considered. The study is continuing with variations in the chosen parameter values and modifications of the assumptions used.

It does seem evident, however, that the use of a mobility device increases scientific return over walking primarily when large loads are to be carried over relatively smooth terrain, or where a very large distance separates the LM from sites which will be visited for only a very short time. The mobility device also gains some advantage if a traverse consists primarily of motion over large distances with few or no site-related activities (no ingress or egress), or if the mobility device permits access to terrain which cannot be negotiated by walking.

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P. Benjamin

Attachment
Tables 1 thru 3
Figures 1 thru 3

MOBILITY TRADEOFF

WALKING

WALKING RATE (KM/HR)	NO. SITES VISITED	TOTAL TIME AT SITES (HR)	TOTAL TIME OF EVA (HR)	TIME AT LAST SITE (HR)	TOTAL BTU CHECK
SITE SEPARATION .25KM					
TIME AT SITE .25HR					
1.00	4	1.000	3.943	.250	4800.
2.00	7	1.525	3.733	.025	4800.
3.00	8	1.793	3.626	.043	4800.
4.00	8	1.971	3.555	.221	4800.
5.00	9	2.043	3.526	.043	4800.
SITE SEPARATION .25KM					
TIME AT SITE .50HR					
1.00	3	1.257	3.840	.257	4800.
2.00	4	1.793	3.626	.293	4800.
3.00	4	2.000	3.543	.500	4800.
4.00	5	2.105	3.501	.105	4800.
5.00	5	2.186	3.469	.186	4600.
SITE SEPARATION .25KM					
TIME AT SITE .75HR					
1.00	2	1.436	3.769	.686	4800.
2.00	3	1.882	3.590	.382	4800.
3.00	3	2.090	3.507	.590	4800.
4.00	3	2.195	3.465	.695	4800.
5.00	3	2.250	3.443	.750	4800.

TABLE 1 - SAMPLE PROGRAM OUTPUT WALKING

MOBILITY TRADEOFF

RIDING

RIDING RATE (KM/HR)	NO. SITES VISITED	TOTAL TIME AT SITES (HR)	TOTAL TIME OF EVA (HR)	TIME AT LAST SITE (HR)	TOTAL BTU CHECK
SITE SEPARATION .25KM					
TIME AT SITE .25HR					
1.00	4	.971	4.471	.221	4800.
2.00	5	1.250	3.983	.250	4800.
3.00	6	1.300	3.800	.050	4800.
4.00	6	1.389	3.681	.139	4800.
5.00	6	1.443	3.610	.193	4800.
6.00	6	1.479	3.562	.229	4800.
7.00	6	1.500	3.533	.250	4800.
8.00	7	1.500	3.510	.000	4786.
9.00	7	1.500	3.472	.000	4763.
10.00	7	1.500	3.442	.000	4745.
11.00	7	1.500	3.417	.000	4730.
12.00	7	1.500	3.396	.000	4717.
13.00	7	1.500	3.378	.000	4707.
14.00	7	1.500	3.363	.000	4698.
15.00	7	1.500	3.350	.000	4690.
SITE SEPARATION .25KM					
TIME AT SITE .50HR					
1.00	3	1.164	4.331	.164	4800.
2.00	3	1.500	3.883	.500	4800.

TABLE 2 - SAMPLE PROGRAM OUTPUT
RIDING

TABLE 3 - ASSUMED METABOLIC COSTS

ACTIVITY	METABOLIC RATE (BTU/HR)	TIME (MIN)
PLSS C/O	900	10
EGRESS LM	2000	10
EQUIPMENT UNLOAD	1400	10
MOB. DEV. SERVICE	1400	15
MOB. DEV. INGRESS	1500	2.5
MOB. DEV. EGRESS	1500	2.5
SAMPLE TRANSFER	1400	10
INGRESS LM	2000	10
EXPERIMENT AT SITE	1400	
WALK	1000	
RIDE	600	

BASED UPON DATA FROM:

Bottomley, T. A., "Working Note - Preliminary Energy Cost Data for Lunar Surface EVA," Bellcomm Working Papers, May 2, 1969.

Benjamin, P., "Observations from the 18th LSOP Meeting," May 22, 1969.

Wood, W. H., "Preliminary Apollo 11 Lunar Surface Operations Plan," FCSD/MSC, May 7, 1969.

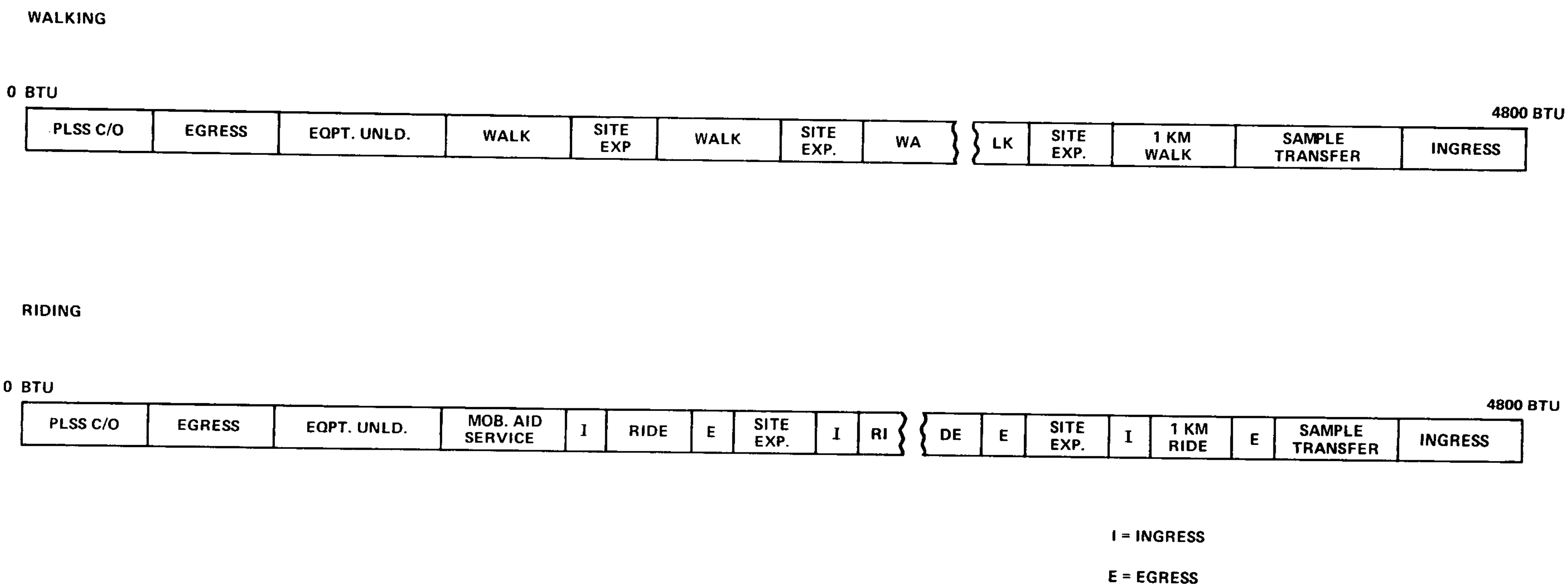

FIGURE 1 - ASSUMED TIMELINE

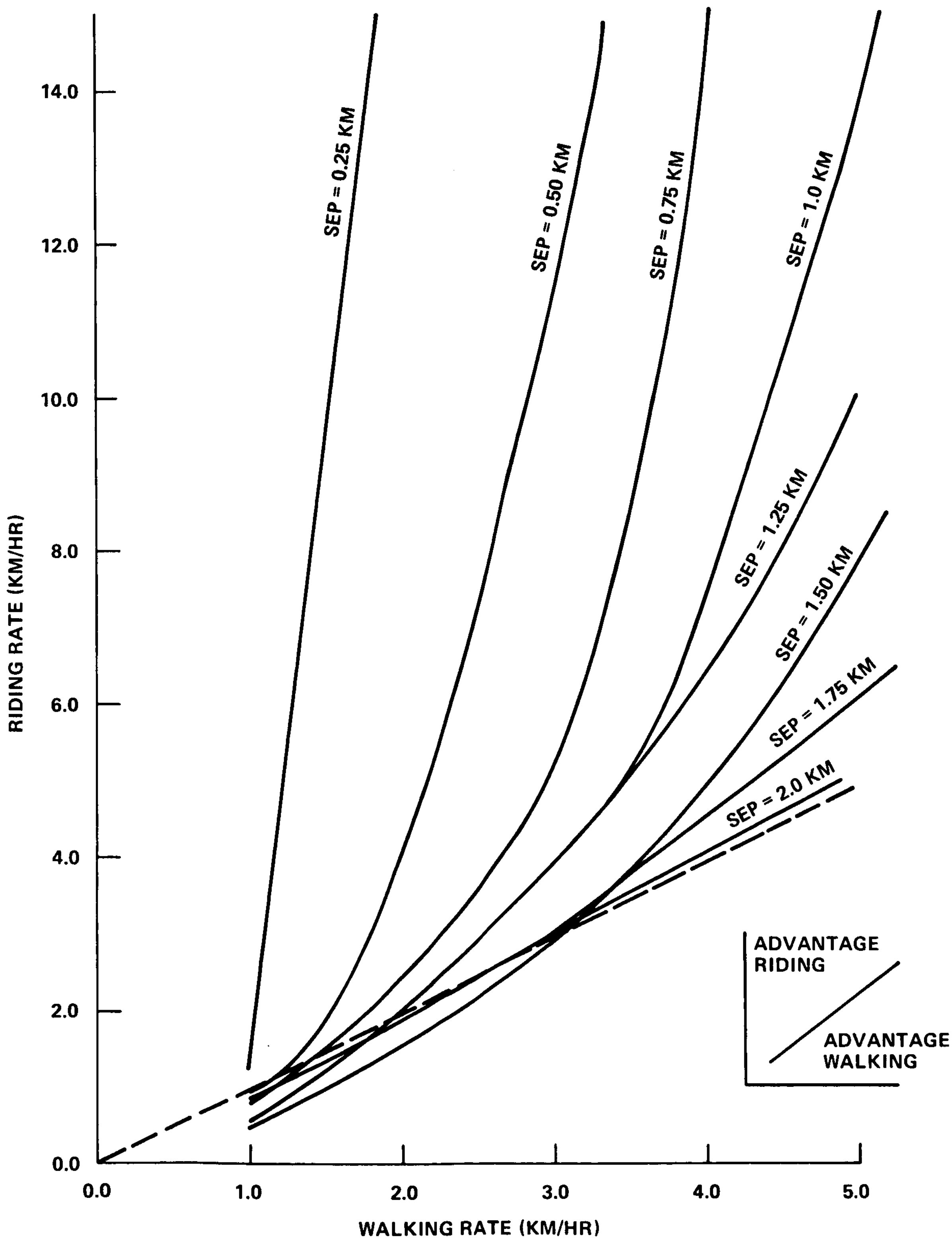

FIGURE 2 - WALKING/RIDING EQUAL PAYOFF
TIME AT SITE = 15 MIN.

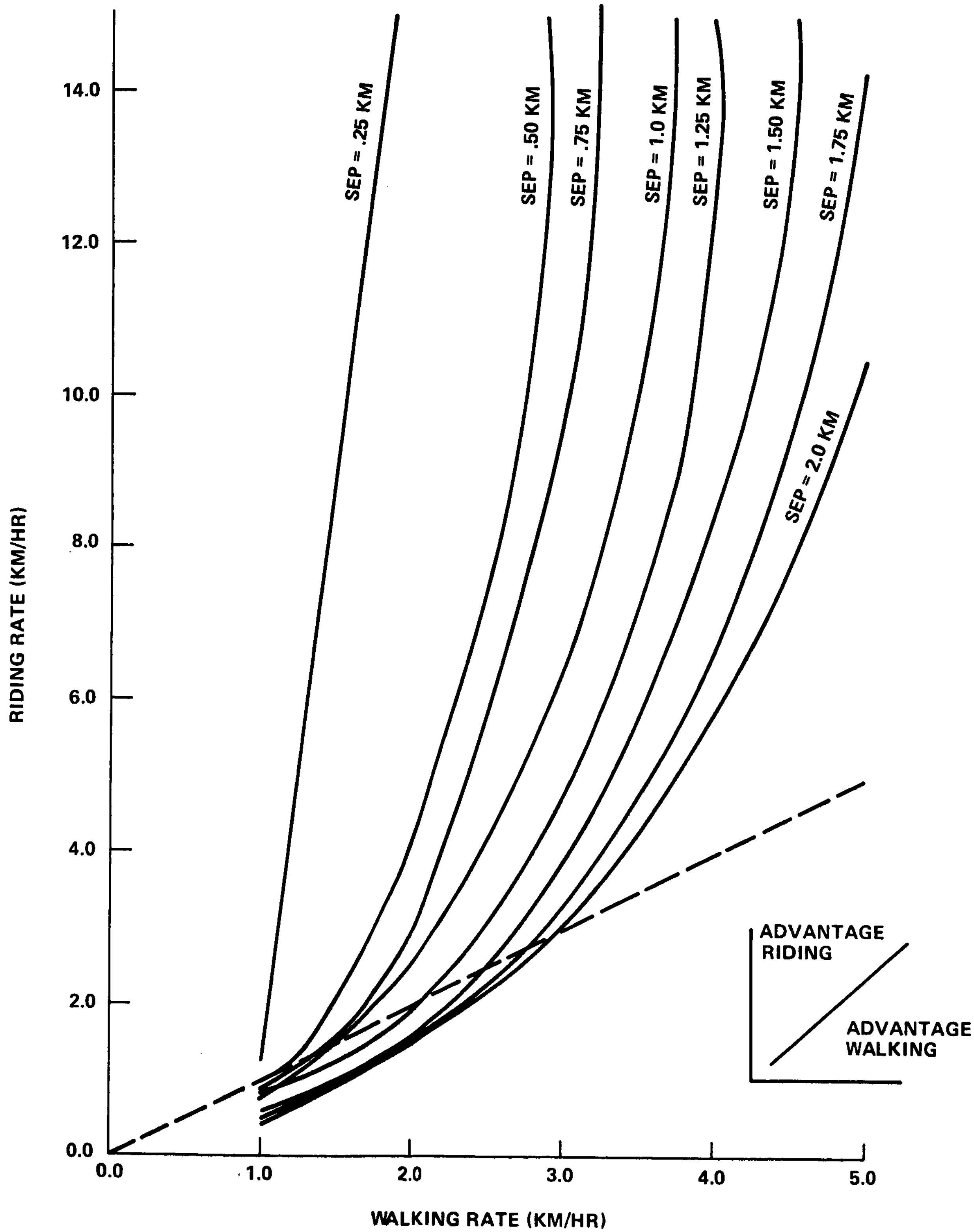

FIGURE 3 - WALKING/RIDING EQUAL PAYOFF
TIME AT SITE = 1 HR.